PROJECT FACT SHEET

CONTRACT TITLE: Advanced Reservoir Characterization in the Antelope Shale to Establish the Viability of CO2-Enhanced Oil Recovery in California's Monterey Formation Siliceous Shales -- Class III

ID NUMBER: DE-FC22-95BC14938

B&R CODE: AC1010000

CONTRACTOR: Chevron USA Inc.
Production Company

ADDR: 5001 California Ave.
P.O. Box 1392
Bakersfield, CA 93309

DOE PROJECT MANAGER:

NAME: Gary D. Walker
LOCATION: NPTO
PHONE: 918/ 699-2083
E-MAIL: gary.walker@npto.doe.gov

CONTRACT PROJECT MANAGER:

NAME: Pasquale R. Perri
PHONE: 661/ 395-6492
FAX: 661/ 395-6542
E-MAIL: patperri@chevrontexaco.com

PROJECT SITE
CITY: Bakersfield **STATE:** CA
CITY: Buena Vista Hills, Kern Cnty **STATE:** CA
CITY: Lost Hills Field , Kern Cnty **STATE:** CA

CONTRACT PERFORMANCE PERIOD:
2/12/1996 to 2/28/2002

PROGRAM: Reservoir Life Extension
RESEARCH AREA: Seismic; Class
PRODUCT LINE: ADIS

CO-PARTICIPANTS:

PERFORMER: Adv Resources Intl, Inc.	**CITY:** Arlington	**STATE:** VA	**CD:**
PERFORMER: Stanford Univ	**CITY:** Stanford	**STATE:** CA	**CD:**
PERFORMER: Core Laboratories	**CITY:** Bakersfield	**STATE:** CA	**CD:**
PERFORMER: Terra Tek, Inc.	**CITY:** Salt Lake City	**STATE:** UT	**CD:**

FUNDING (1000'S)	DOE	CONTRACTOR	TOTAL
PRIOR FISCAL YRS	4849	4850	9699
FY 2002 CURRENT OBLIGATIONS	0	0	0
FUTURE FUNDS	0	0	0
TOTAL EST'D FUNDS	4849	4850	9699

OBJECTIVE: Increase oil recovery from the Monterey/Antelope Siliceous Shale through the application of an innovative reservoir management plan.

March 2002

PROJECT DESCRIPTION:

Background: The Buena Vista Hills field, discovered in 1952, has produced only 9 million barrels of oil representing 6.5% of the estimated 130 million barrels of original-oil-in-place. The current status of the reservoir indicates that it is producing at 40% of its original reservoir energy. In addition, production from wells in this field, and in the Antelope Shale in general, has been declining, and the wells are in danger of being abandoned. Several methods were tried to improve the reservoir productivity. Technologies such as waterflooding, acid stimulation treatments, and induced hydraulic fractures were implemented and, although some were proven successful, the overall oil recovery from the Antelope Shale still remains low at 6.5%.

However, based on the reservoir characterization of Buena Vista Hills field, the Antelope Shale is unsuitable for a CO2 flood. Budget Period II has been transferred to a 10-acre site in the Lost Hills field for the pilot CO2 flood demonstration. The Lost Hills Belridge diatomite is a unique reservoir and its unusual properties such as extremely small pore size, high porosity and low permeability have led to historically, low primary oil recovery (3 - 4% OOIP). Due to the low primary recovery and large amount of remaining oil in place, Lost Hills presents an attractive target for EOR. CO2 flooding has the potential for dramatically improving the recovery from the Lost Hills Belridge diatomite. Compared to Buena Vista Hills, the reservoir at Lost Hills has several advantages for a CO2 flood: (1) the temperature is lower, which will improve the partial-miscibility of the oil with CO2; (2) the reservoir is shallower so operating pressure will be lower; (3) the oil is heavier, which will improve the partial miscibility of the oil with CO2; (4) and the Lost Hills reservoir has overall lower permeability due to the absence of thin sandstone layers in the targeted intervals which will improve the areal sweep.

Work to be Performed: This project will demonstrate the economic viability and widespread applicability of an innovative reservoir management plan for a CO2 flood project in the fractured siliceous shales of the Monterey Formation. Advanced reservoir characterization and fracture analysis will be applied to optimize the design of the CO2 - based enhanced oil recovery project. The first step will be an application of a variety of advanced reservoir characterization techniques to determine the production characteristics. The production characteristics will be used in laboratory coreflood and reservoir models to evaluate how the reservoir will respond to the application of advanced secondary recovery and EOR processes. The second step will be to design and implement an advanced EOR pilot demonstration by injecting CO2 in an immiscible phase. To increase potential for successful demonstration of CO2 technology developed from Phase I, transfer of Phase II has been proposed for the CO2 pilot flood project from the low oil saturation/ and reservoir pressure (800 psi) at Buena Vista Hills to the higher oil saturation/ and relatively greater reservoir pressure of the Chevron owned Lost Hills Oil Field, located 45 miles north of Bakersfield, California.

PROJECT STATUS:

Current Work: The project Budget Period I was conducted at Buena Vista Hills field. Results from Budget Period I indicated that Buena Vista Hills field was not a good CO2 flood candidate. Budget Period II was transferred to Lost Hills field for the field demonstration of CO2 flooding. Project is in Budget Period II.

Scheduled Milestones:

Finalize Pilot CO2 Flood Design	10/99
Drilled and Completed Pilot Wells	08/00
Facilities Installation Completed	08/00
Commenced CO2 Injection	09/00
Began WAG Cycles	05/01

Accomplishments: Reservoir characterization of Brown and Antelope shales completed. First coreflood analysis of siliceous shales. Data from 160 wells has been compiled into a database and used for high resolution and structural mapping. The first high-resolution crosswell reflection images obtained in any oil field in the San Joaquin Valley. Project demonstrated the first successful application of the TomoSeis acquisition system in siliceous shales. The study at Buena Vista Hills was the first detailed reservoir characterization of San Joaquin Valley siliceous shales. Outcrop analysis of rock fractures has been completed and shows how fractures can act as permeable pathways. Core analysis indicates that siliceous shale layers not capable of high oil saturation, but the sandstone layers have high oil saturations. A mineral model has been built to determine lithology variations and oil saturations in siliceous shales. A comprehensive 3D-earth model was completed. With regards to crosswell seismic tomography: (1) researchers at the Seismic Tomography Project at Stanford University (under Jerry M. Harris) have developed a modification of their original centroid frequency shift scheme, which now includes the rise time of the direct arrival as a way of improving the estimate of the degree of frequency shift in the waveform; (2) we are currently working on improved velocity imaging algorithms which will properly handle well deviations and will estimate small amounts of elastic anisotropy; (3) we are also developing improved reflection imaging algorithms which can handle well deviations, elastic anisotropy, and complex structure.

CO2 injectivity tests at Lost Hills field have been completed and indicate that CO2 injection will not be a problem. However, there was some concern with pre-mature CO2 breakthrough because of the small well spacing (2.50 acre patterns). The CO2 facility construction was completed for the well gauging and the liquid CO2 injection facilities. Two existing injection wells

were successfully repaired. Three observation wells and two replacement injection wells were drilled and completed. The pilot construction and all associated well work were completed and CO2 injection commenced on August 31, 2000. A comprehensive CO2 monitoring program has been put in place and baseline surveys taken prior to the injection of CO2.

CO2 injection has continued into all four pilot injectors, intermittently in 2001, as we encountered re-occurring sanding problems with the producers. It appears that the CO2 injection may have played a role in the sanding problems. Through December 31, 2001, approximately 216,514 MCF of CO2 has been injected at the average rate of 239 MCF/D per injector. An initial oil response was observed in one well (11-8E) as a result of CO2 injection. However, the initial oil response in well 11-8E has been curtailed due to sanding problems with it and four other pilot producers.

CO2 injection was suspended in early May 2001 as the project continued to be hampered by excessive sanding of the producers. Five wells had to be shut-in for remedial procedures: 11-8D, 11-8E, 12-8B, 12-8C, and 12-8D. As a result of the sanding problems, we reverted back to water injection in the four pilot injectors (11-8WR, 11-8WAR, 12-7W, and 12-8W).

The 5 problem producers were remediated and returned to production. CO2 injection on was restarted on September 5, 2001 after being shut in since mid-May 2001. After several weeks, the sanding problems returned. We once again reverted back to water injection in the four pilot injectors as we contemplate what new remedial actions to take. We are also considering short WAG cycles (one week of CO2 followed by one week of water injection) to maybe also help alleviate the sanding problems.

The following accomplishments are a result of the comprehensive CO2 monitoring program to date:

Cased hole resistivity logging in observation wells show oil saturation changes in and above the injection interval after 1 year of CO2 injection.

Electromagnetic (EM) surveys run by EMI Inc. and Lawrence Livermore National Laboratory show resistivity changes in injection zone due to CO2.

Presence of injection tracers in seven of ten producers indicates the existence of a natural fracture system.

Injection profiles range from poor to excellent coverage.

Oil geochemistry samples collected after 1 year of CO2 injection are being analyzed.

Crosswell seismic survey interpreted by Lawrence Berkeley National Laboratory.

Baseline and follow-up gas samples are being analyzed by Oak Ridge National Laboratory.

Seven of ten producers have had sanding problems possibly due to CO2 injection.

TECHNOLOGY TRANSFER:

Technology/Information Transfer: Hoversten, G.M., 2001, Crosswell Seismic and Electromagnetic Monitoring of CO2 Injection, SEG Development and Production Forum, Taos, N.M.

Lee, K.H., Kim, H.J., Tseng, H.W., and Wilt, M., 2001, Electromagnetic Methods for Geothermal Exploration, Annual Meeting Geothermal Resources Council, San Diego (August 26-29).

Montgomery, S.L., Morea, M.F., 2001, Antelope Shale (Monterey Formation), Buena Vista Hills Field: Advanced Reservoir Characterization to Evaluate CO2 Injection for Enhanced Recovery, AAPG Bulletin, v. 85, n. 4.

Wilt, M., Zhang, P., Morea, M., Julander, D., Mock, P., 2001, Using Crosswell Electromagnetics to Map Water Saturation and Formation Structure at Lost Hills, SPE Western Regional Meeting, n. 68802.

Public Relations: Edward R. Spaulding, Public Affairs Manager, Chevron USA Production Company, (661) 633-4500, email: ersp@chevrontexaco.com.

Chip Power, The Bakersfield Californian, Staff Writer, email: ppower@bakersfield.com.

Updated By: **Dan Ferguson** Date: **1/9/2002**